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SURFACE-WATER SUPPLY FOR IRRIGATION IN THE VERMILION RIVER BASIN, LOUISIANA

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HYDRAULICS DIVISION

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SURFACE-WATER SUPPLY FOR IRRIGATION IN THE VERNILION RIVER BASIN, LOUISIANA[1]

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ABSTRACT

This paper presents an analysis of surface-water problems in the Vermilion River basin based on data collected in connection with an investigation of the water resources of southwestern Louisiana.

During the period of investigation, 1949-51, inventories were made of the available supplies and of diversions for the irrigation of rice. Records available from miscellaneous sources made it possible to include 1948 in the analytical phases of the investigation. Data were collected to indicate the components of water use on rice fields. Water requirements at point of stream diversion were measured at pumping plants supplying 60 percent of the total acreage planted in the Vermilion River basin. The extent and intensity of salinity intrusions were traced by means of an extensive water-sampling program.

Two years of critical water shortage, 1948 and 1951, were experienced during the period for which data is reported. During these two years the demand for water exceeded the supply from Vermilion River basin by 180,000 and 125,000 acre-feet, respectively.

Records of water use on 44 rice fields in southwestern Louisiana indicated a total average water requirement of 31.7 inches of depth, of which 22.4 inches are consumed by evapotranspiration during the period of submergence. From these records it is computed that in an extremely dry season an average of 27 inches of water must be delivered to the fields. Conveyance losses, between point of diversion from the streams and point of delivery to the fields, averages 35 percent of the diversion volumes. From these data it is computed that the maximum probable diversion requirement is 42 inches of depth, or 3.5 acre-feet per acre. Although not completely independent, this figure for maximum diversion agrees remarkably well with that measured at pumping plants in the Vermilion basin during 1948, 3.64 acre-feet per acre.

Based on maximum plantings of 70,000 acres, in an extremely dry season, a rate of diversion of 3.5 acre-feet per acre would require a supplementary water supply to the Vermilion River of about 215,000 acre-feet. The maximum rate of delivery of the supplementary supply is estimated to be about 1,500 cubic feet per second.

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Salinity intrusions into the Vermilion River do not occur according to the typical wedge pattern because of the small density difference between the fresh-water supply and the water in the Vermilion Bay.

INTRODUCTION

The Geological Survey has recently completed a water resources investigation in southwestern Louisiana, conducted in cooperation with the Louisiana Departments of Public Works and Conservation. The surface-water phase of this investigation covered the period 1949-51 and dealt primarily with problems related to water supply for the irrigation of rice. Pumping records and some salinity data for 1948 were available from other sources. Because of the critical problems occuring in the 1948 season these data were included in the analytical phases of the investigation.

This paper presents briefly the general plan of investigation and discusses, in detail, problems in the Vermilion River basin. Analyses have been confined, however, to the basic elements of supply and demand without reference to specific proposals to alleviate the water shortage.

Description of Vermilion River Basin

The description given in the following paragraphs is taken, with modifications and additions, from a report of the Corps of Engineers published as Senate Document No. 93, 77th Congress, 1st Session.

The Vermilion River basin is in southwestern Louisiana, principally in the parishes of St. Landry, Lafayette, and Vermilion. The basin is about 55 miles long and about 23 miles wide at the latitude of St. Martinville. The total area of the basin above the Intracoastal Waterway is 652 square miles. The general location of the Vermilion River basin and some of its topographic features are shown in figure 1.

The principal physiographic features of the area are the coastwise plains, or prairies, and the coastal marsh. The prairie lands constitute the higher and northernmost part of the area. They are eroded remnants of a former delta of the Mississippi River system. The elevation of the prairie lands increases from approximately 2 feet at their juncture with the coastal marsh to slightly above 70 feet near Opelousas. The coastal marsh is an area of very low relief, the surface elevations generally being less than 2 feet above mean gulf level.

The prairie lands in the basin present a wide, flat expanse of lands peculiarly suited to the culture of rice. The light, loamy surface soil is closely underlain by dense and nearly impervious subsoils. In general, surface drainage channels are small, having depths of only a few feet below the general land surface.

The Vermilion River is formed by the confluence of Bayous Carencro and Fusilier (fig. 1) and traverses a total distance of about 73 river miles to its mouth at Vermilion Bay. Bayou Fusilier interconnects with Bayou Teche. Another connection is through Ruth Canal. For the first 16 miles of its course, the river flows in a general southerly direction

near the escarpment marking the eastern limit of the prairie. Near Lafayette, the stream turns southwestward through the prairie lands and meanders in a well-defined valley 300 to 1,000 feet in width to the vicinity of the city of Abbeville, a distance of about 31 miles. Below Abbeville, the river follows a general southerly course, traversing the low-lying southern fringe of the prairies and the coastal marsh for a distance of approximately 25 miles to its mouth at the Western end of Vermilion Bay, an estuary of the Gulf of Mexico.

Channel improvements for flood control and navigation cause the Vermilion River to be tidal throughout its entire length. The range in stage of normal tides at the mouth is about 10 inches.

Delineation and Discussion of Water-Supply Problems

The natural flow of the Vermilion River in seasons of low runoff is small compared to irrigation requirements. Acreages of rice irrigated by diversions from Vermilion River during the four years included in this report were:

Year	Acres
1948	54,500
1949	51,500
1950	49,500
1951	47,000

Diversions from Vermilion River for uses other than irrigation of rice are negligible. A small volume of water enters the Vermilion River through Bayou Fusilier, a natural channel (see fig. 2). Flow through Bayou Fusilier may be either to or from the Vermilion River, depending on the relative water-surface elevations of Bayou Teche and the Vermilion River. Since about 1920, supplementary supplies have been diverted from Bayou Teche into the Vermilion River through the Ruth Canal. Water available from Bayou Teche, however, has not been sufficient in critical years to meet the needs for supplementary water in the Vermilion River basin.

During periods when diversions for irrigation exceed the available upstream supply in the Vermilion River, water from Vermilion Bay is drawn into the channel. If a period of deficient flow persists, saline waters from the bay encroach many miles of the channel. Serious crop losses result either from the use of the saline water or from refusal to use it.

It is the usual practice in the area to reject water with more than 400 to 500 parts per million of chloride for use on rice in the earliest stages of plant development. Water of 2,000 ppm, or slightly more, is sometimes used in the very late stages, if necessary, but usually results in crop damage. There is little experimental evidence for this area to indicate the harmful effects on subsequent crops grown on land irrigated with water of high chloride concentrations. The water drawn from Vermilion Bay during periods of excessive pumping rarely exceeds 2,500 ppm of chloride but may average 2,000 ppm over extended periods of time.

General Plan of Surface-Water Investigation

As with most water-resources investigations, the investigation in southwestern Louisiana involved inventories of supply and demand and studies of problems resulting from water shortages.

The head-water areas of the important southwestern Louisiana streams are well covered by gaging stations. Gaging the flow in the tidal reaches of Vermilion River was not practicable in this investigation because of the expensive methods that would be required. It was necessary, therefore, to estimate flow from large areas in each river basin. These flow estimates were based on rainfall, using methods calibrated against existing gaging station records.

Estimates of the total diversions for irrigation in each river basin were made by sampling process in which diversions were measured at a selected group of the larger irrigation pumping plants. In the Vermilion River basin, records were obtained for two large plants serving about 60 percent of the total acreage irrigated in the basin.

To obtain these records of diversion, it was necessary for the Geological Survey to make many measurements of flow rates under varying combinations of lift and speed for each individual pump. From 10 to 25 measurements of flow were made for each pump in order to determine its rating. As discharge pipes, under positive pressure, were generally inaccessible, out of the ordinary procedures had to be adopted. Nearly all measurements were made by use of pitot rod meters inserted in pipes on the suction side of the pumps.

In another phase of the investigation data were obtained for 44 rice fields to determine the components of water requirement at the field level. A number of tests were run to determine the volumes of irrigation water going into soil-moisture storage and seepage.

During the 1951 irrigation season, in which serious water-supply deficiencies developed, the movements of saline waters in the river channels were traced by an extensive water-sampling program.

Presentation and Analysis of Streamflow and Diversion Data

Records of streamflow in the Vermilion River basin are available for two gaging stations in the headwater streams, Bayous Bourbeau and Carencro (see fig. 1). The runoff from 56 square miles, or 8.6 percent of the total basin area, is measured by these stations. Runoff from the ungaged area of 596 square miles was estimated on the basis of records for the two gaging stations. As Bayous Bourbeau and Carencro have virtually no contribution of flow from ground water, the estimates of flow from the ungaged area are essentially estimates of surface runoff. Ground-water seepage volumes are considered in a subsequent section of this paper and are discussed in more detail in a companion paper by P. H. Jones, (1954). Diversions from Bayou Teche through Bayou Fusilier and the Ruth Canal were computed from gage readings, miscellaneous discharge measurements, and records of gate openings at the Ruth Canal control structure furnished by the Corps of Engineers. Computations of daily flow were combined into weekly volumes for analysis of water-supply deficiencies.

Daily pumpage for the two sample pumping plants in the Vermilion River basin (see location, fig. 1) were also combined into weekly volumes. Estimates of total weekly diversions for irrigation were computed by increasing the pumpage at the two plants by the ratio of the total area irrigated in the basin to the area served by the sample plants.

Streamflow and diversion for irrigation during the growing seasons of 4 years, 1948-51, are presented graphically in figures 2-5. Weekly streamflow and diversion is shown in the upper half of each illustration. Volumes of diversion in excess of current streamflow, hereinafter called deficiencies, are indicated by the hachured areas. These deficiencies represent water drawn from Vermilion Bay, and are, also, the volumes of supplementary upstream supplies required to prevent salinity intrusion. The lower half of each illustration shows volumes of flow, diversion, and deficiency accumulated from the first week of diversion. The difference between accumulated diversion and accumulated streamflow on any date represents the net deficiency or excess in streamflow from the beginning of pumping to that date. The accumulated deficiency line in the lower section of each figure represents the cumulative total of the hachured areas in the upper section, or the accumulated gross deficiency.

A comparison of figures 2-5 shows that the 1948 and 1951 season were more critical than the others of the four for which records are presented, with 1948 being the year of greatest deficiency. The seasons in 1949 and 1950 were periods of adequate water supply. The gross deficiency for the entire 1948 season was 118,000 acre-feet as compared with 75,000 acre-feet in 1951 (figures 2 and 5). These deficiencies would have been greater had not supplementary supplies been diverted from Bayou Teche.

For the 5-month period, April through August which covers nearly the entire irrigation season, the lowest precipitation of record for southwestern Louisiana as a whole occurred in 1925 and 1951. The rainfall on the Vermilion River basin, computed from isohyetal maps drawn on the basis of all available information, was 16 and 18 inches in the years 1948 and 1951, respectively, for the period April to August. For the corresponding period in 1925 the average precipitation at three stations in the basin was 13.7 inches. Furthermore the 1925 season was preceded by 12 months of critically subnormal rainfall. However, according to available acreage records, plantings in 1925 were considerably less than in 1948. Thus, although 1925 was undoubtedly a year of serious salt-water encroachment, the disparity between water supply and demand in the Vermilion River basin in 1948 was probably the greatest of record.

Figure 6 shows the approximate location in the river channel of water having a salinity concentration of 500 ppm of chloride during the 1948 and 1951 seasons. Mile distances are referenced to the mouth of the river. Much of the information shown on figure 6 was derived from data collected by Acadia-Vermilion Rice Irrigating Company. Although diversions in relation to streamflow were much greater in 1948 than in 1951 (compare figures 2 and 5), figure 6 shows that critical salinity conditions developed much earlier in 1951 than in 1948. The large

volume of runoff that went into Vermilion Bay during April 1948 probably became pocketed in the bay near the mouth of the river. Much of it probably was reclaimed during the subsequent weeks of excessive pumping, thus delaying the encroachment of salt water. Streamflow during April 1951 was considerably less than that during April 1948. However, streamflow in March preceding the two seasons was nearly the same, about 100,000 acre-feet. For the 6-month period, October through March preceding the 1948 season the streamflow is estimated to have been about 507,000 acre-feet as compared with about 372,000 acre-feet for the corresponding period prior to the 1951 season. In general, the amount of streamflow in the months between the close of the preceding season and the beginning of the current season is probably a less reliable index of the pre-season freshening of Vermilion Bay than is the amount of flow in March and April.

A study of figure 6 shows that when salinities became critical in 1948 they remained so throughout the irrigation season. The acreage irrigated with Vermilion River water in 1948 was 54,500 acres. The diversion requirement was high and streamflow was low. Because of the great demand for water, pumping plants on the river were forced to continue heavy pumping despite the poor quality of the water. In 1951, only 47,000 acres was irrigated with surface water, supply and demand were not so critically out of balance as in 1948. In 1951, the plants were shut down for several periods to allow the fresh-water flow to accumulate in channel storage. This storage was pumped back in subsequent periods. During each period of pumping following a period of shutdown, more water was pumped back than had been allowed to go into storage. The additions came from Vermilion Bay water diluted to tolerable quality by the fresh-water flow. Tidal movements of water in the channel assist greatly in the mixing process.

Figure 7 shows three salinity profiles obtained during the 1951 season. Profiles were run at approximately weekly intervals throughout the critical part of the season. It will be observed that in the lower reach of the channel, salinities averaged about 2,000 ppm of chloride. The variability in quality in the lower reach reflects primarily the variability of water drawn from Vermilion Bay. Observations in the bay area indicate salinities in East and West Cote Blanche Bays are, at many times, lower than in Vermilion Bay because of the movement of fresh water from the Atchafalaya Bay area. During times of high southwest winds or abnormally high tides, water with higher salinity concentrations, enters Vermilion Bay through Southwest Pass. This water is not as saline as gulf water, which is about 19,000 ppm, because off-shore currents of Atchafalaya River water cause come dilution. Water reaching the mouth of Vermilion River, therefore, may change in quality with change in wind direction or with tidal variations.

The fresh-water supply in the upper reach of the river averaged 50 ppm, or slightly less. The profiles shown on figure 7 show a zone of mixing from 10 to 15 miles in channel length. The profile for July 17 demonstrates a time when the large plant at mile 38.3 was taking more than the entire river flow. An important feature of the salinity intrusion in Vermilion River is that it moves as a front rather than as a wedge protruding upstream near the bed of the channel. Samples taken

near the surface and near the bottom at any point in the river always have very nearly the same salinity. As Vermilion Bay water is never pure gulf water, but is always diluted to a great degree by Atchafalaya River water or by excess Vermilion River flow, density differences are not great enough to produce the typical wedge movement of the saline waters.

Consideration of Effect of Ground Water on Surface-Water Supply

As explained in the predecing discussions, the estimates of flow from the Vermilion River basin are essentially estimates of surface runoff. Thus, there is the possibility that these estimates of flow are too low and that inflow from ground water may have increased the actual supply. On the other hand these estimates may be high because of river water that might have infiltrated to ground water. Mr. Jones (1954) has demonstrated the deletorious effects of flow exchange between ground and surface water in the basin. It, therefore, becomes important to examine the data at hand for evidence of the magnitude of the exchange.

During the period April 30 to August 12, 1948, 178,000 acre-feet of water was diverted from the Vermilion River. The available supply from upstream sources during this period was about 63,000 acre-feet. Thus 115,000 acre-feet of water was pumped which did not originate as current runoff from the Vermilion River basin or by diversions from Bayou Teche. This water represented ground-water inflow, Vermilion Bay water made usable by dilution, excess streamflow in antecedent periods subsequently withdrawn from storage in Vermilion Bay, return flow from irrigated fields, channel storage, or water entering from adjacent basins through the Intracoastal Waterway. The volumes of water contributed by each of these sources cannot be determined to any high degree of accuracy, but it is possible to compute fair estimates of them.

To compute the volume of Vermilion Bay water originating from Atchafalaya Bay and the gulf that was usable by dilution, the assumption is made that water from Atchafalaya Bay and water entering Southwest Pass, when mixed in Vermilion Bay averages about 2,000 ppm of chloride. Records collected by the Acadia-Vermilion Rice Irrigating Company have been used to compute the mean salinity of the diverted water. During the period April 30 to August 12, 1948, the chloride in the water pumped by the two sample plants in the basin averaged 450 ppm of chloride. If all water pumped during this period (178,000 acre-feet) averaged 450 ppm, Vermilion Bay water averaged 2,000 and the freshwater supply from all sources contained 50 ppm then out of the 178,000 acre-feet pumped, about 37,000 acre-feet was Vermilion Bay water made usable by dilution. This volume of water derived from Vermilion Bay was computed by use of the following dilution equation:

$$450(178{,}000) = 50(178{,}000 - X) + 2{,}000X$$

where X equals the volume of Vermilion Bay water made usable by dilution. Accounting for this volume reduces the deficiency from 115,000 acre-feet to 78,000 acre-feet.

Consideration now will be given to the volume of fresh water drawn from storage in Vermilion Bay or from adjacent basins through Intracoastal Waterway. Records indicate that the salinity at Intracoastal City, near the mouth of the Vermilion River, increased from 950 on June 18 to 1,850 ppm on June 23. The salinity had been much lower prior to June 18 and was higher after June 23. By June 25 the river channel was filled with high-salinity water up to about 38 miles above the mouth. All fresh water in storage in the bay and in the channel, therefore, was exhausted by June 25. The total deficiency developed prior to June 24 (see figure 2) was 69,000 acre-feet, which may be assumed to have been the approximate volume of water available from storage in Vermilion Bay and in the river channel and of that drawn from other basins through the Intracoastal Waterway. It is probable, however, that the greater part of this water had its origin as preseason runoff from the Vermilion River basin. The excess streamflow that went into the bay in the four weeks prior to the beginning of the period considered was 69,000 acre-feet.

Accounting has now been made for 37,000 acre-feet of water which originated in the bay and gulf area, and 69,000 acre-feet of preseason runoff reclaimed from storage. Of the 115,000 acre-feet of excess pumpage during the period being considered, 106,000 acre-feet has been approximately identified as a source. This leaves 9,000 acre-feet to be accounted for as ground-water inflow and return flow by drainage from rice fields. As all errors in estimating the water-budget components heretofore computed are reflected in this figure (9,000 acre-feet) further breakdown of the excess pumpage, as to source, is not practicable.

Computations for a like period during the 1951 season produced results similar to those outlined for 1948 and, therefore, will not be reported in detail. The computations for both years indicate that the exchange between ground and surface water in the Vermilion River basin is of such small magnitude in comparison with the other qualities involved in the water budget for an irrigation season that accurate computation of the exchange volumes cannot be made from the data presented in this paper. These computations also indicate that return-flow volumes do not figure importantly in the water-supply budget during periods of water shortage.

Rates of Diversion for Irrigation

From the records of diversion at the sample pumping plants in the Vermilion River basin the seasonal diversion requirements per acre for the four years included in this study are as follows:

Year	Acre-feet per acre
1948	3.64
1949	2.72
1950	3.46
1951	3.24

Generally, in seasons of higher rainfall a greater part of the irrigation requirement is furnished by precipitation than in low-rainfall years, with a consequent reduction in required diversions. As has already been

established, the 1948 season was a period of near-record low rainfall. The diversion rate of 3.64 acre-feet per acre for that season represents a probable maximum rate for any one year.

From 44 rice fields records obtained over the three season period, 1949-51, the conservation of precipitation for crop use was as follows:

Year	Number of Records	Precipitation During Submergence (inches)	Precipitation Retained on Field (inches)	Percent Precipitation Retained
1949	16	18.33	11.4	62
1950	16	17.84	11.6	65
1951	12	8.63	6.1	71

Of the percentage of precipitation not retained on the fields for crop use, part is intercepted by the rice plants and return to the atmosphere by evaporation and part is lost by runoff over levee tops if rainfall amounts are excessive. Because of interception losses the portion of rainfall available for crop use probably reaches a maximum of not more than 75 percent. A summary of the other results obtained from the 44 field records follows:

	Water depth in inches
Consumptive use during period of submergence	22.4
Drained from fields during period of submergence	2.1
Drained from fields at end of season	5.2
Soil moisture storage and seepage	2.0
Total	31.7
Average length of period of submergence	89 days

All the total water requirement of about 32 inches must be furnished by irrigation except that part supplied by rainfall. During the 1951 season an average of 8.6 inches fell on the fields during the period of submergence. In the worst of years a minimum of 6 inches precipitation during the period of submergence may safely be assumed. If an average of 75 percent of the 6 inches of precipitation is available for crop use, the effective rainfall would be 4.5 inches. Reducing the total requirement of 31.7 inches by 4.5 inches of effective precipitation leaves an estimated maximum of 27 inches of irrigation water to be delivered to the fields in the most unfavorable year.

For the southwestern Louisiana area as a whole, conveyance losses between point of diversion at the streams and the point of delivery to the fields averages 35 percent of the water diverted. The maximum irrigation requirement of 27 inches, then, is 65 percent of the maximum diversion rate. The computed maximum diversion requirement is 42 inches of depth or 3.5 acre-feet per acre. This figure for maximum probable diversion agrees with that computed from diversion records during the 1948 season (3.64 acre-feet per acre). Because of the method of computing the conveyance losses, the two figures computed for maximum diversion requirement are not entirely independently determined. However, the two methods of determining diversion requirements show remarkably close agreement.

Estimate of Supplementary Water-Supply Requirements

As stated previously, runoff from the Vermilion River basin is very low by comparison with diversion requirements. The table below lists the flow in the Vermilion River by sources for the irrigation season months, April to August, in the years 1948-51.

Year	Vermilion Basin (acre-feet)	Bayou Fusilier (acre-feet)	Ruth Canal (acre-feet)	Total (acre-feet)
1948	72,700	5,500	80,400	159,000
1949	349,000	24,400	119,000	492,000
1950	400,000	23,200	118,000	541,000
1951	61,000	15,100	73,000	149,000

This table shows that in low-flow years more than one-half the available supply comes from outside the basin. The experience of the 1948 and 1951 seasons, as well as other years of past record, indicate that the preseason assistance from outside the basin is not sufficient to meet the need for water in critical years.

Although during the season in 1951 the total water supply in the Vermilion River from all sources was nearly equal to the need, there were a number of weeks when deficiencies developed that resulted in salt-water encroachment in the channel. The ground-water investigation conducted in the Vermilion River basin indicates clearly that to prevent contamination of the ground-water aquifer the encroachment of salt water in the Vermilion River channel must not be allowed at any time. Also, encroachment by salt water in any part of the channel at any time should be prevented so that all farmers in the basin may be supplied with fresh water. This means that the deficiencies in streamflow should be counterbalanced week by week, as they occur, by supplementary supplies.

During 1948 and 1951 the hachured areas on figures 2 and 5 represent the additional volumes of water that would have been needed during each week to prevent encroachment of saline water into the channel. Supplementary supplies of 118,000 and 75,000 acre-feet, in addition to those available from Bayou Teche, would have been needed in 1948 and 1951, respectively, to prevent encroachment of salt water.

It is a well recognized fact that, to prevent salt-water encroachment in streams entering highly saline waters, supply rates in excess of demand rates are required if artificial barriers are not used. Even if supply exceeds demand, encroachment will result from the reverse gradient created by the density difference between fresh and salt water. There is no evidence in the data for the Vermilion River to indicate that the density difference between the fresh-water supply and the Vermilion Bay water is great enough to be an important consideration. A study of the movement of the salt-water front (fig. 6) in relation to the flow balance (figs. 2 and 5) reveals that large excesses of fresh water are not required to cause the zone of contact between fresh water and salt water to move downstream in the Vermilion River.

The effect of return flow from rice field drainage has also been neglected in the computation of supplementary supply needs. Although there is a small volume of drainage from time to time during the season, the largest volumes result from drainage of the fields just before harvest. This drainage comes too late in the season to be an important factor. Neglect of return flow results in computed deficiencies slightly larger than actual deficiencies but, in effect, introduces a small factor of safety in the planning of alleviating works.

Heretofore in this paper all computations of deficiency have been based on the Vermilion River flow, including that diverted from Bayou Teche. The gross deficiency during the 1948 and 1951 seasons was given as 118,000 and 75,000 acre-feet, respectively. If the only flow available during these years had been that originating within the basin, the gross deficiencies would have been about 180,000 and 125,000 acre-feet, respectively, during those years.

Although provisions for a supplementary supply of 180,000 acre-feet per season probably would have prevented salinity encroachment in all years of past experience, consideration of a possible maximum future requirement is desirable.

For the period April to August 1925, the runoff from the Vermilion River basin is estimated to have been about 30,000 acre-feet, not including flow through the Ruth Canal or Bayou Fusilier. The maximum acreage irrigated with Vermilion River water in any previous year cannot be determined accurately but is believed to have been about 70,000 acres. At a maximum diversion rate of 3.5 acre-feet per acre on 70,000 acres, a total diversion volume of about 245,000 acre-feet would have been required. If this volume of diversion should be required in a year like 1925 and if it is assumed that the 30,000 acre-feet runoff is distributed during the season so that all is usable, about 215,000 acre-feet of water would be needed from outside sources to prevent drawing water from Vermilion Bay.

The probability of maximum diversion demand coinciding with the worst of water-supply years cannot be accurately predicited. It is probable, however, that plans be alleviate the water-supply problem in the Vermilion River basin should include the possibility that a supplementary supply of as much as 215,000 acre-feet of water may be needed.

The maximum rate of which supplementary water must be delivered to the basin is also an important factor. In the week of maximum diversion in the four years for which records have been studied, the diversion rate was 0.33 acre-foot per acre. During a consecutive period of 9 weeks in 1948 the average weekly diversion was 0.25 acre-foot per acre. To irrigate 70,000 acres at a rate of 0.3 acre-foot per acre per week would require the delivery of water from a supplementary source at a rate of about 1,500 cubic feet per second. This delivery rate is computed on the assumption that the flow originating within the basin would be negligible at the time of maximum demand. There were 7 weeks during the 1948 season in which there was no runoff from the Vermilion River basin.

SUMMARY

1. Salinity encroachments into the Vermilion River channel occur whenever diversions exceed the supply from upstream sources. The difference in density between the fresh-water supply in the river and the water which enters the channel from Vermilion Bay is not great enough to cause the intrusions to follow the typical wedge pattern.

2. During the four year period, 1948-51, salinity encroachments in the Vermilion River were serious in two years, 1948 and 1951. In these years only about 45 percent of the available water supply for irrigation originated as runoff from the Vermilion River basin.

3. Available water supplies during 1948 and 1951 were 117,000 and 73,000 acre-feet, respectively, below the volumes required to prevent salinity intrusions. Had there been no supplementary supply diverted from Bayou Teche in these years the deficiencies would have been 180,000 and 126,000 acre-feet, respectively.

4. Preseason runoff may, under certain conditions, be reclaimed from storage in the Vermilion Bay. It appears reasonably certain that the runoff during 3 or 4 weeks only just prior to the beginning of a period of excessive pumping may be reclaimed from bay storage. This was an important factor in the early part of the 1948 season and delayed salinity intrusion for several weeks.

5. Analysis of the data presented in this paper indicates that flow exchanges between ground and surface water in the Vermilion River basin are small in magnitude by comparison with the other water volumes involved in the water-supply problems.

6. Analysis of existing data indicates that return flow from rice-field drainage is of little consequence in the water-supply budget.

7. Measurement of water use on 44 rice fields show the following results:

	Water depth in inches
Evapotranspiration during period of submergence	22.4
Drained from fields during period of submergence	2.1
Drained at end of season	5.2
Soil moisture storage and seepage	2.0
Total water requirement	31.7
Average length of period of submergence	89 days

8. Records show that loss of water between point of diversion at the streams and point of delivery at the fields in southwestern Louisiana averages about 35 percent of the total volume of diversion.

9. The maximum probable seasonal diversion requirement is 3.5 acre-feet per acre of rice planted.

10. The acreage of rice now being irrigated with water diverted from the Vermilion River averages about 50,000 acres. The largest acreage of past years was probably about 70,000 and it is reasonably safe to assume that with assured water supply the acreage may again approach that figure.

11. A computation based on an assumed maximum planting of 70,000 acres of rice in a year of minimum rainfall and runoff, as in 1925, shows that a total of 215,000 acre-feet of water would have to be diverted into the Vermilion River from outside sources to prevent crop losses and the encroachment of salt water.

12. Under the assumptions made in item 11, above, the maximum rate at which the supplementary water would have to be brought into the Vermilion River basin is computed to be about 1,500 cubic feet per second.

REFERENCE

"Ground-Water Conditions in the Lower Part of the Vermilion River Basin, Louisiana," by Paul H. Jones, Proceedings-Separate No. 490, ASCE, September, 1954.

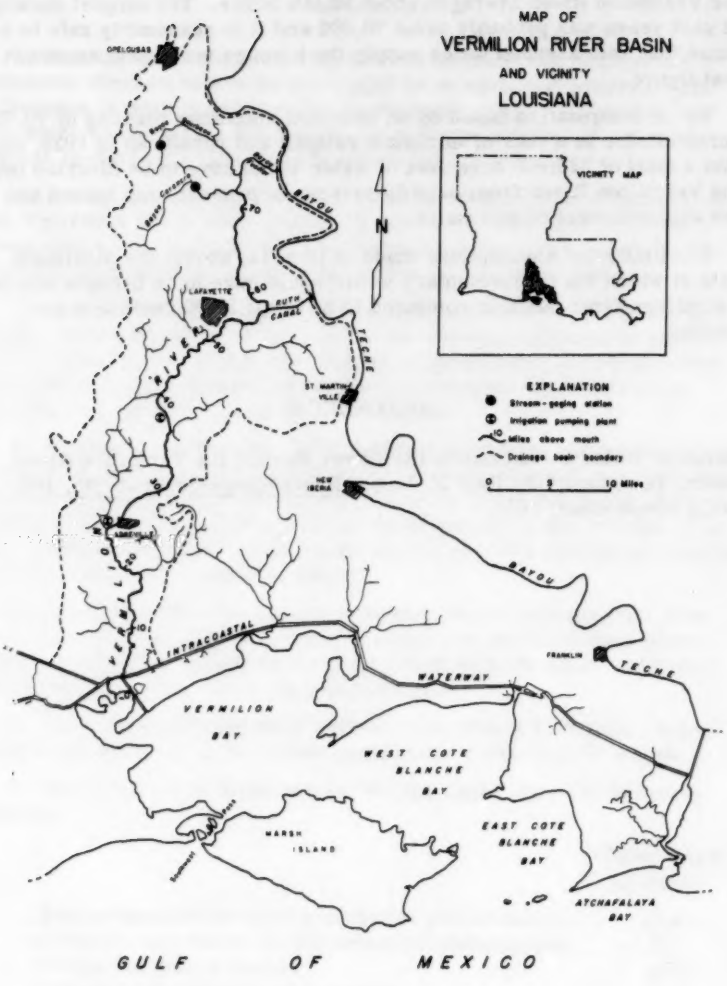

Figure 1. Map of Vermilion River basin and vicinity, Louisiana

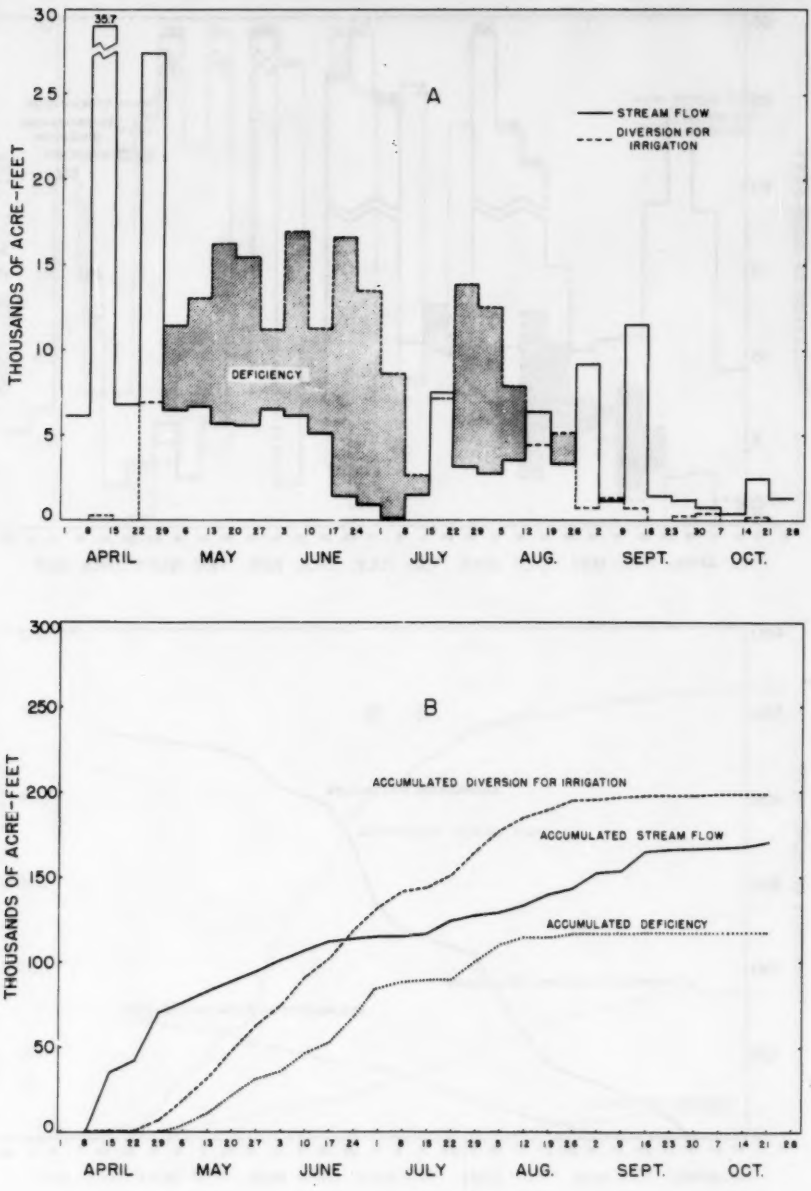

Figure 2. Streamflow and diversions for irrigation, Vermilion River basin, 1948: A, Weekly streamflow and diversion volumes; B, Accumulated streamflow, diversions, and deficiencies.

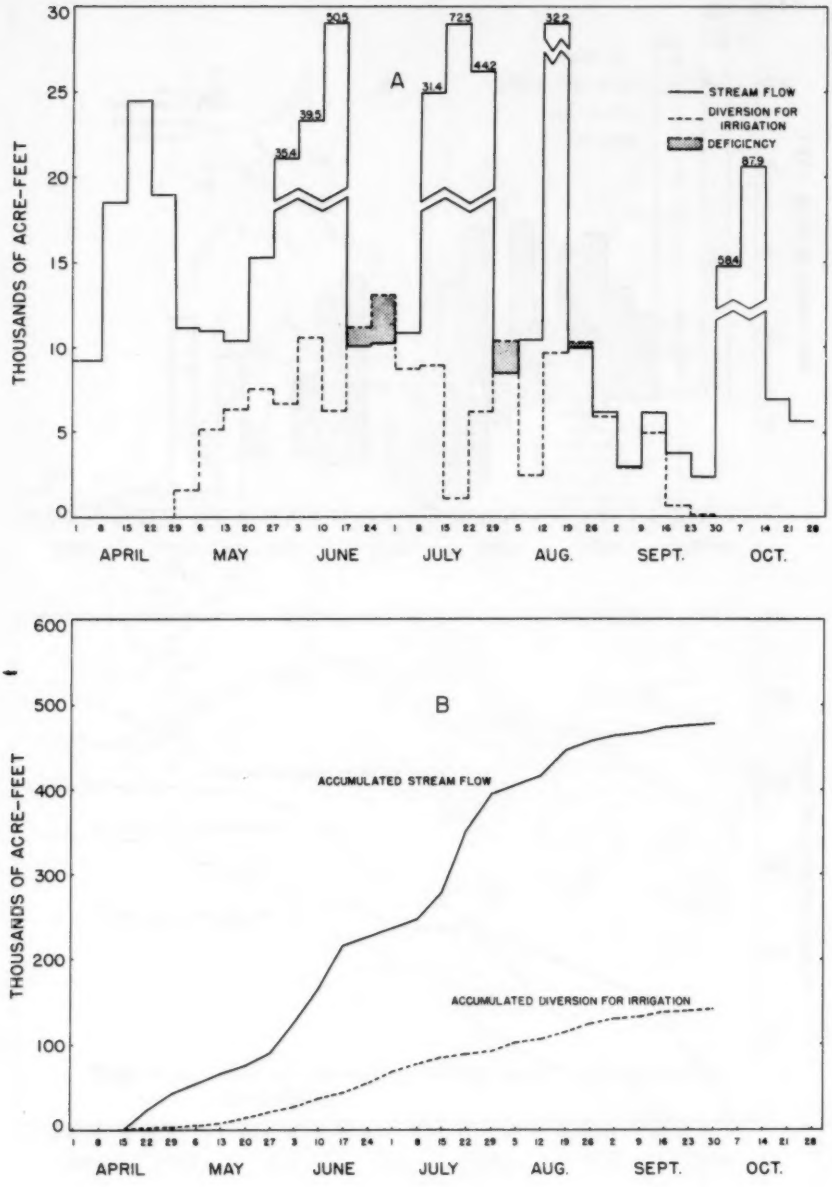

Figure 3. Streamflow and diversions for irrigation, Vermilion River basin, 1949: A, Weekly streamflow and diversion volumes; B, Accumulated streamflow, diversions, and deficiencies.

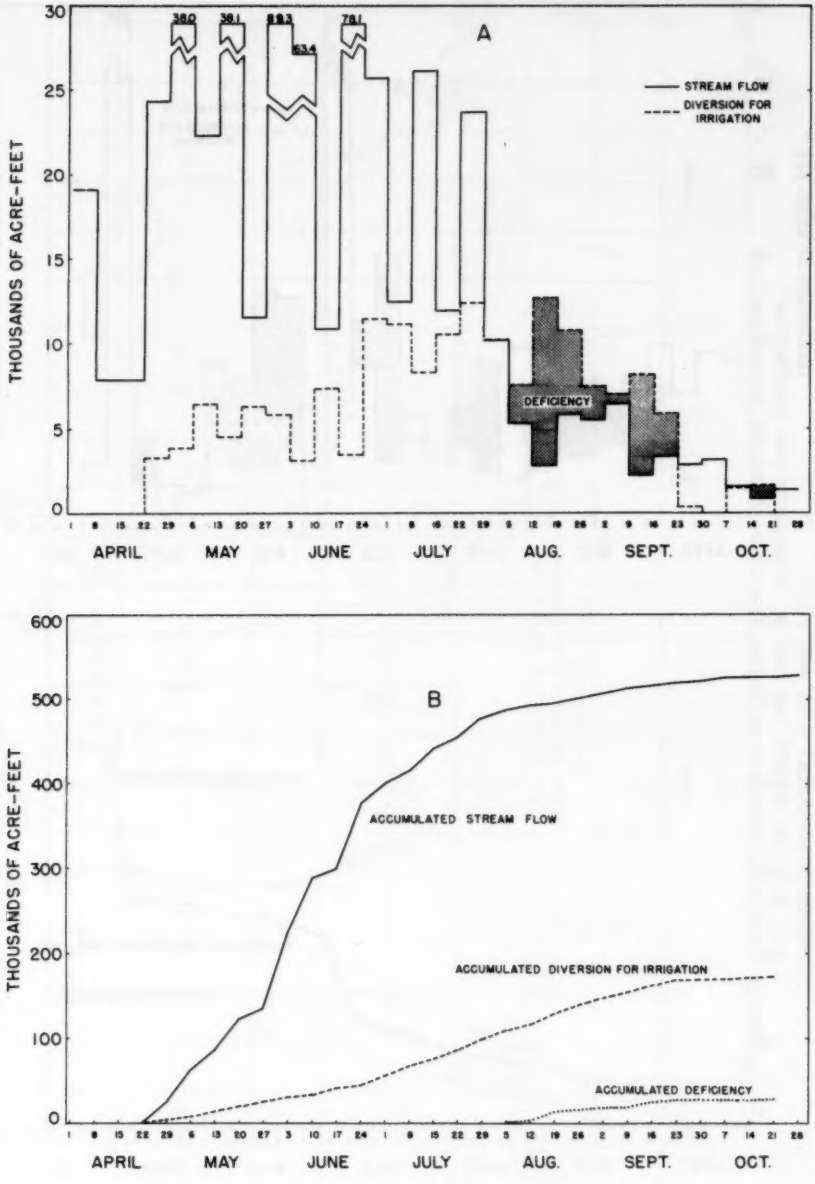

Figure 4. Streamflow and diversions for irrigation, Vermilion River basin, 1950: A, Weekly streamflow and diversion volumes; B, Accumulated streamflow, diversions, and deficiencies.

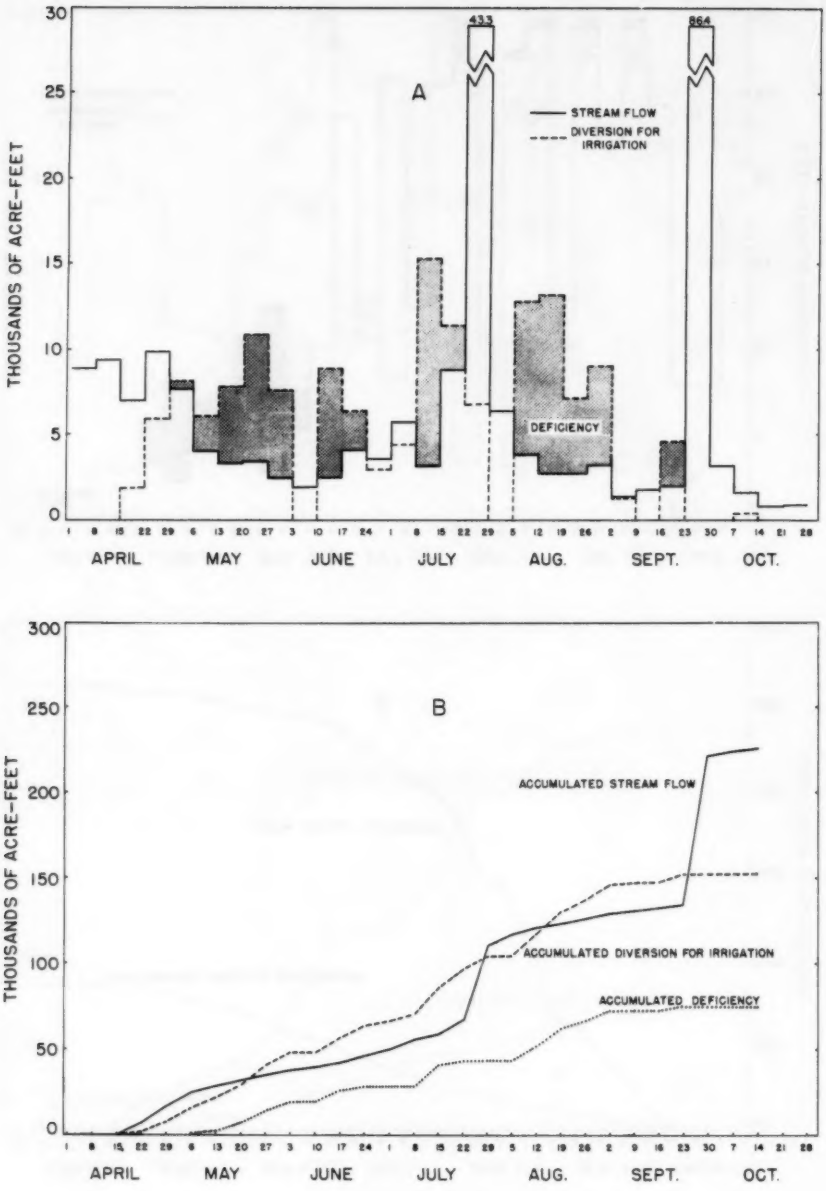

Figure 5. Streamflow and diversions for irrigation, Vermilion River basin, 1951: A, Weekly streamflow and diversion volumes; B, Accumulated streamflow, diversions, and deficiencies.

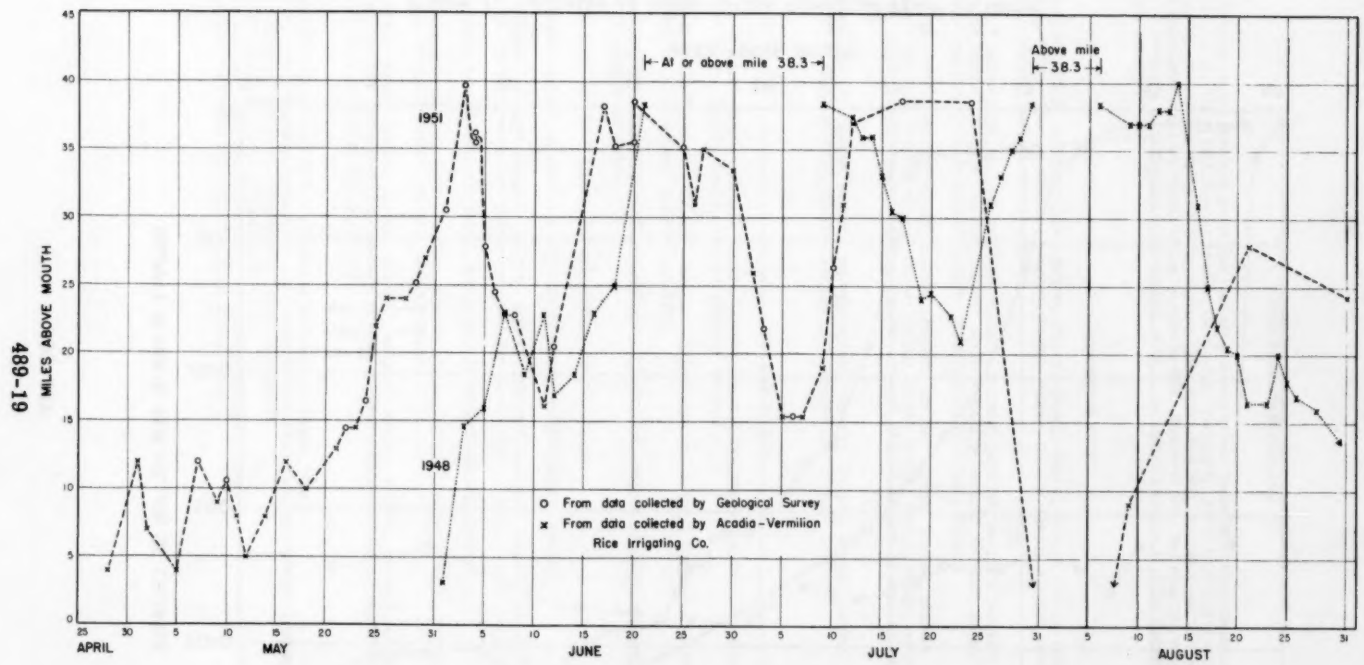

Figure 6. Channel location of water having a chloride concentration of 500 ppm during periods of diversion for irrigation, Vermilion River, 1948 and 1951.

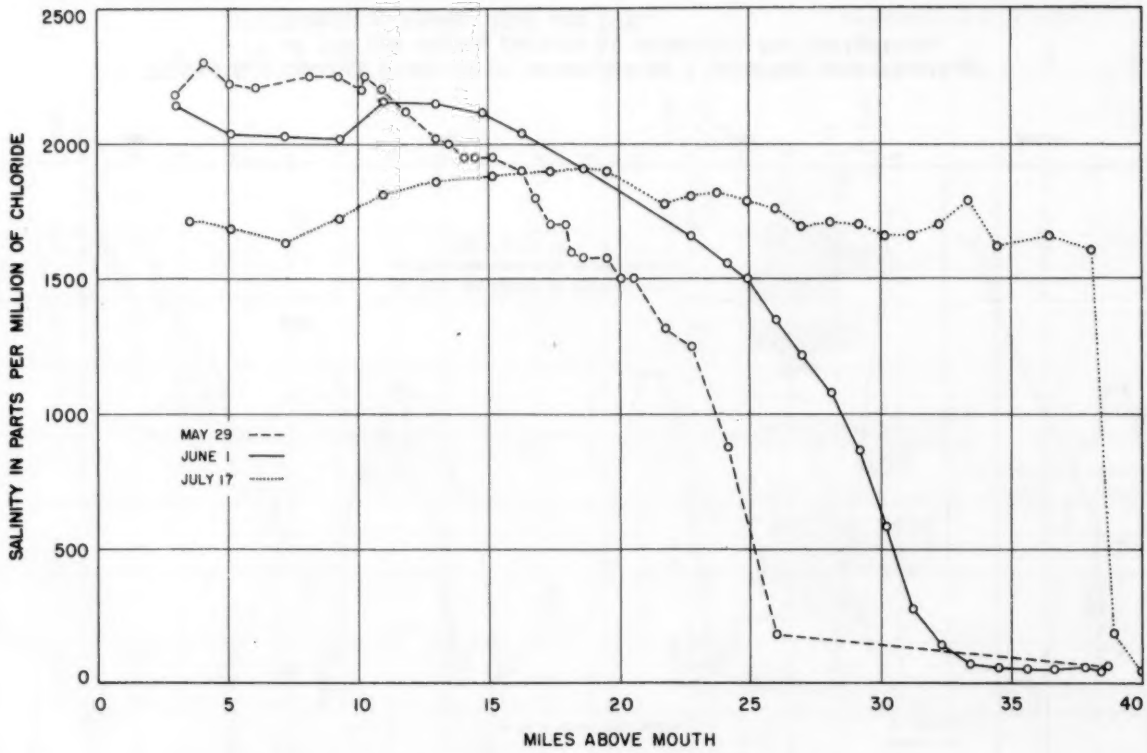

Figure 7. Salinity of water in the Vermilion River on three selected dates in 1951.

PROCEEDINGS-SEPARATES

The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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OCTOBER:[b] 290(all Divs), 291(ST)[a], 292(EM)[a], 293(ST)[a], 294(PO)[a], 295(HY)[a], 296(EM)[a], 297(HY)[a], 298(ST)[a], 299(EM)[a], 300(EM)[a], 301(SA)[a], 302(SA)[a], 303(SA)[a], 304(CO)[a], 305(SU)[a], 306(ST)[a], 307(SA)[a], 308(PO)[a], 309(SA)[a], 310(SA)[a], 311(SM)[a], 312(SA)[a], 313(ST)[a], 314(SA)[a], 315(SM)[a], 316(AT), 317(AT), 318(WW), 319(IR), 320(HW).

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FEBRUARY: 398(IR)[d], 399(SA)[d], 400(CO)[d], 401(SM)[c], 402(AT)[d], 403(AT)[d], 404(IR)[d], 405(PO)[d], 406(AT)[d], 407(SU)[d], 408(SU)[d], 409(WW)[d], 410(AT)[d], 411(SA)[d], 412(PO)[d], 413(HY)[d].

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APRIL: 428(HY)[c], 429(EM)[c], 430(ST), 431(HY), 432(HY), 433(HY), 434(ST).

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JULY: 457(AT), 458(AT), 459(AT)[c], 460(IR), 461(IR), 462(IR), 463(IR)[c], 464(PO), 465(PO)[c].

AUGUST: 466(HY), 467(HY), 468(ST), 469(ST), 470(ST), 471(SA), 472(SA), 473(SA), 474(SA), 475(SM), 476(SM), 477(SM), 478(SM)[c], 479(HY)[c], 480(ST)[c], 481(SA)[c], 482(HY), 483(HY).

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a. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
b. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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